NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Space Weather Information and Electric Reliability

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Space Weather Operations and Research Infrastructure Workshop

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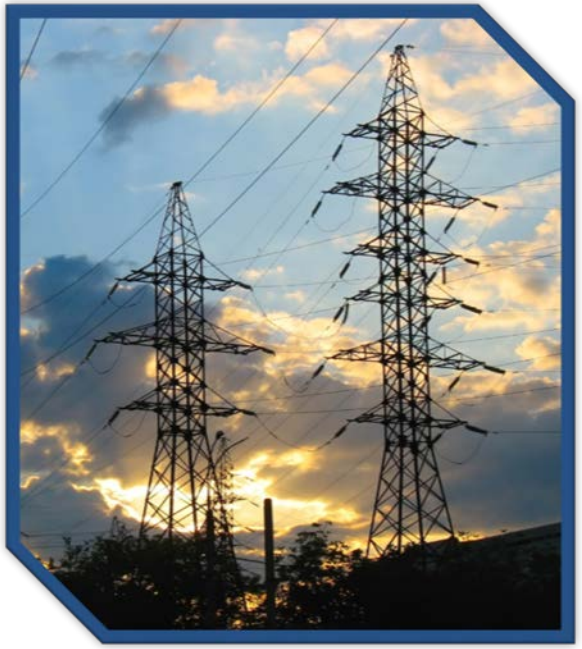
RELIABILITY | RESILIENCE | SECURITY




Electric Reliability Organization Mission

To ensure the reliability and security of the North American bulk power system

- Develop and enforce reliability standards
- Assess current and future reliability
- Analyze system events and recommend improved practices
- Encourage active participation by all stakeholders
- Accountable to regulators in the United States (FERC) and Canada (Canada Energy Regulator and provincial governments)



Space Weather Information Needs

Owners and operators have an ongoing need for Space Weather Information. It is used to:

- ***Operate*** the bulk power system
- ***Plan*** the bulk power system
- ***Assess risks*** to system reliability and resilience

GMD Risk to the Bulk Power System

- Severe GMD Event can cause
  - Voltage Collapse (Blackout)
  - Damage to transmission system power transformers

March 13, 1989 Geomagnetic Disturbance

General Discussion (cont.)

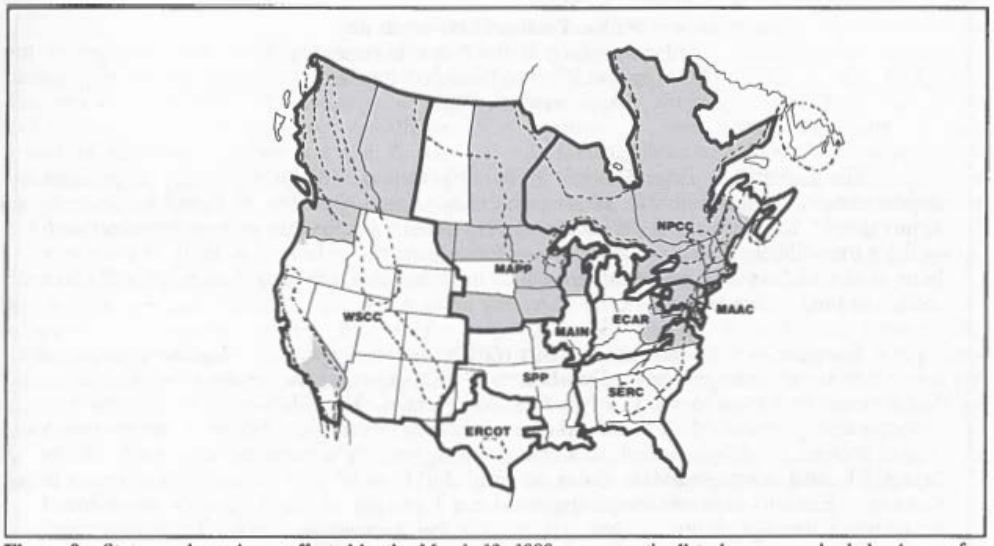
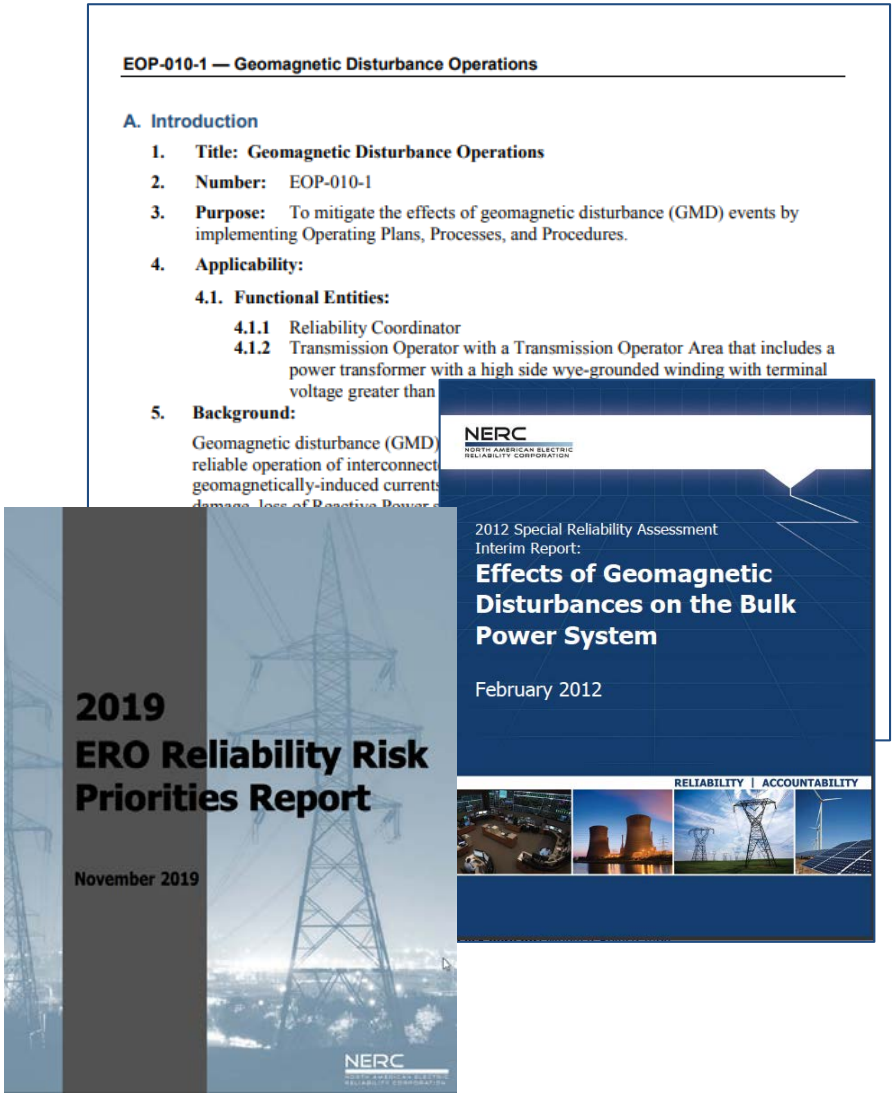


Figure 9 - *States and provinces affected by the March 13, 1989 geomagnetic disturbance are shaded. Areas of igneous rock formations also shown.*

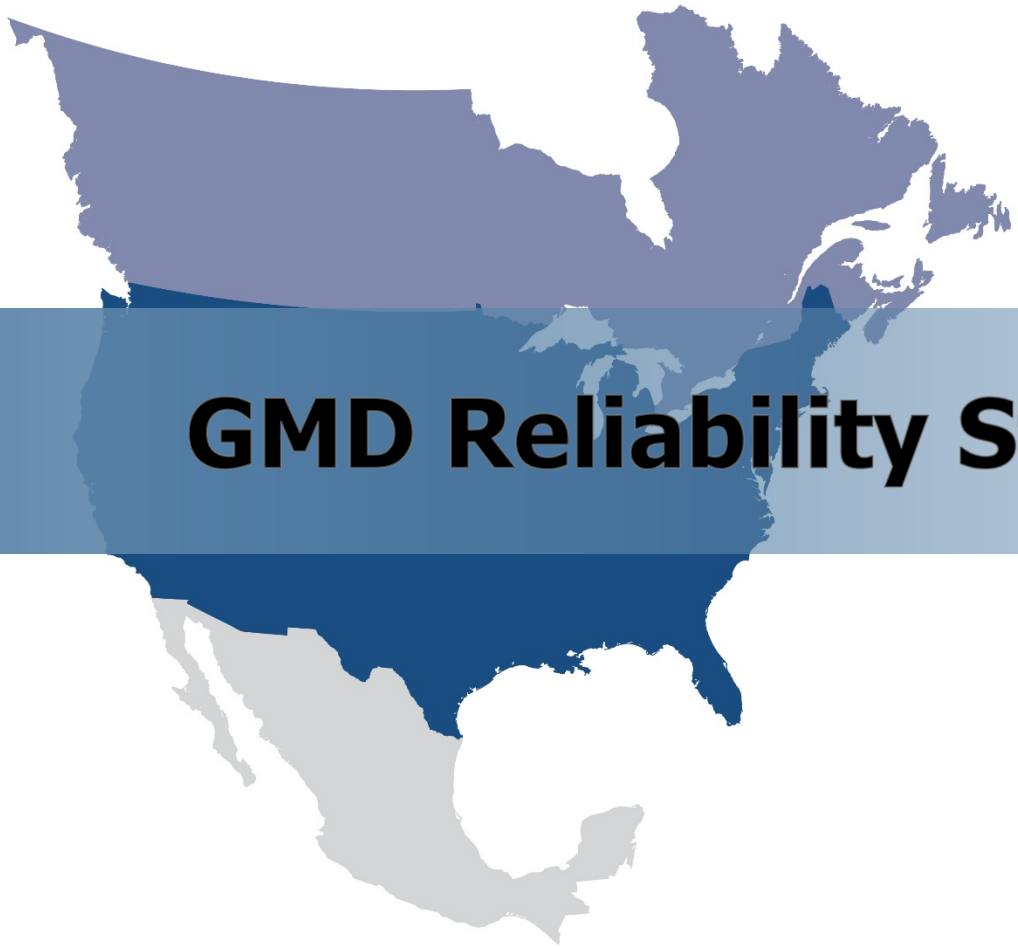
GMD Risk Reduction Efforts

- Reducing risks to the BPS from space weather continues to be an ERO priority
- GMD risk mitigation activities include:
  - Implementation of GMD Reliability Standards
  - Ongoing research with Electric Power Research Institute (EPRI) and other collaborators
  - Implementation of new data collection program to advance validation and research



GMD Task Force

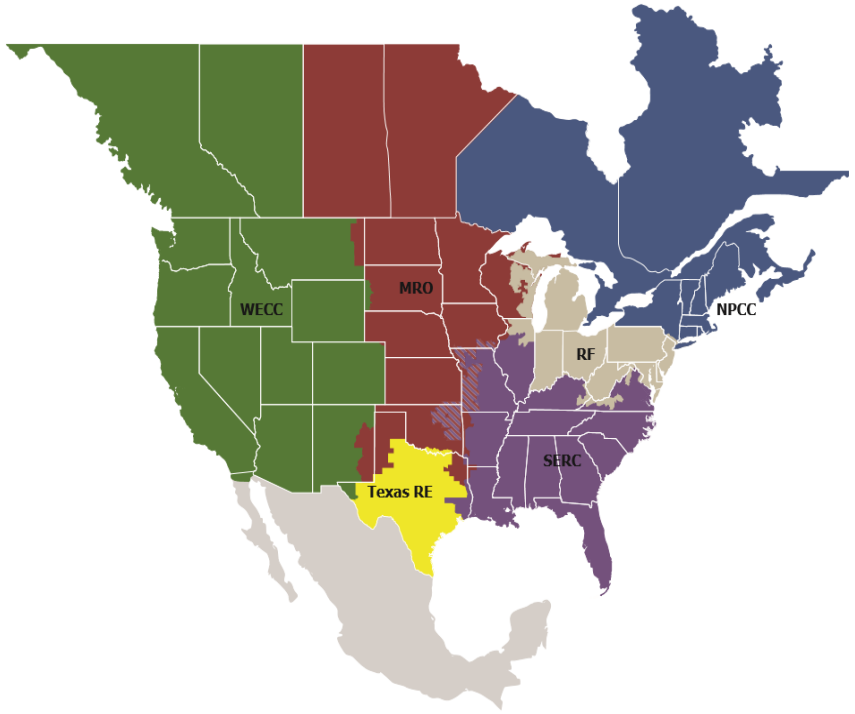
- NERC GMD Task Force collaborates with researchers, agencies and utilities across North America
  - EPRI
  - North American Transmission Forum
  - NOAA Space Weather Prediction Center (SWPC)
  - NASA, Canadian Space Agency
  - U.S. Geological Survey, Natural Resources Canada
  - U.S. National Labs
  - North American Electric Utilities and Transmission System Operators
  - Equipment Manufacturers and Software Tool Developers



GMD Reliability Standards

North America GMD Standards Milestones

- May 2013 – NERC began development of two GMD standards
- April 2015 – GMD Operations standard became effective
- January 2017 – GMD Vulnerability Assessment standard became effective
  - Requirements implemented over a 5-year period



MRO	Midwest Reliability Organization
NPCC	Northeast Power Coordinating Council
RF	ReliabilityFirst
SERC	SERC Reliability Corporation
Texas RE	Texas Reliability Entity
WECC	Western Electricity Coordinating Council

EOP-010: Operating Procedures

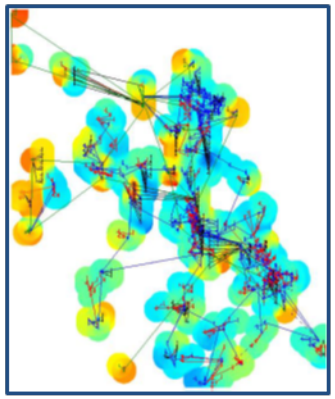
- Requires grid operators to have procedures for mitigating GMD impacts
  - Increased situational awareness
  - System posturing
  - Reconfiguration
- North American grid operators receive alerts from SWPC and Space Weather Canada

System Operator in Texas (Electric Reliability Council of Texas)

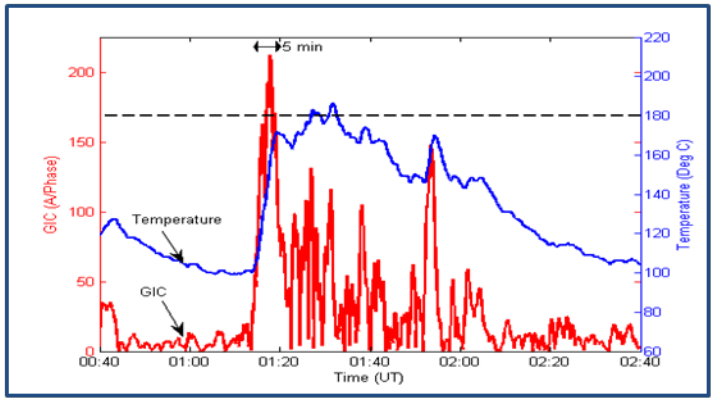
TPL-007: GMD Assessments

- Requires grid planners and asset owners to assess and mitigate risks of voltage collapse and equipment damage from GMD

Use Benchmark Geoelectric Field to model GIC → Study voltage collapse and transformer thermal risks → Identify Corrective Action Needs
- System Upgrades
- Operating Procedures



System Voltage Assessment

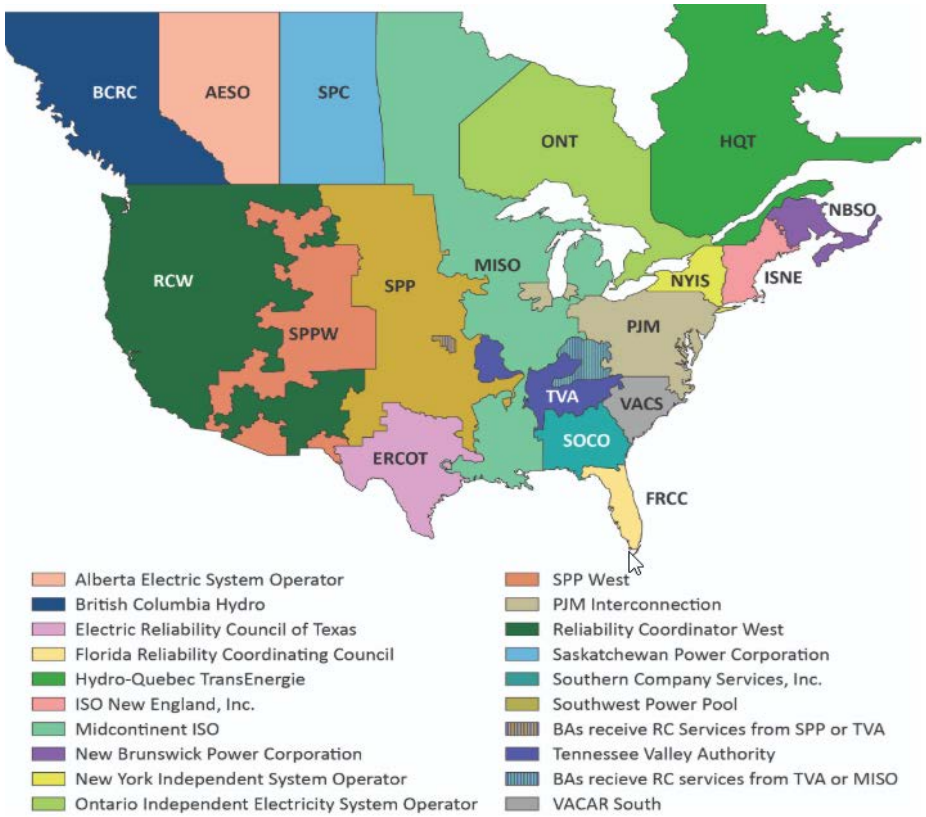


Transformer Thermal Simulation

Operating Actions

Reliability Coordinator Notifications

- SWPC – NERC Hotline provides connectivity directly to the top-level reliability coordinators
- Reliability Coordinator Information System (RCIS) is used for communicating with the 250+ transmission operators and generation balancing authorities



Situational Awareness Indicators

Triggers for initiating operator actions

- Space Weather Information
  - SWPC Alerts, Warnings, and information
  - Space Weather Canada information
- Electric System Operator Information
  - GIC monitors
  - System voltage and reactive power
  - System harmonic levels
  - Transformer diagnostics (internal component temperature and gas analysis)

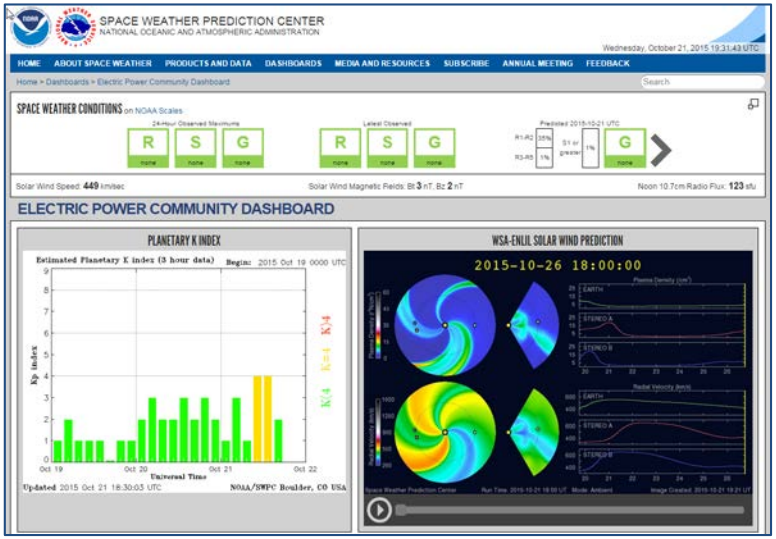
Power Transformer with Installed GIC Monitor and Internal Temperature Sensors

Operating Actions: Three Day Horizon

- Operators increase situational awareness and prepare for power system contingencies
  - Notify field personnel of potential for on-site monitoring
  - Assess restoration (blackstart) contingency preparations
- System posturing for resilience
  - Return equipment to service
  - Delay scheduled maintenance outages
  - Modify protective relay settings if needed for expected GIC harmonic levels

Operating Actions: Event Day Horizon

- Operator monitoring
  - Space weather information from SWPC
  - Electric system conditions (voltage, reactive resources)
  - Critical equipment conditions (transformer heating, noise, and vibration)
  - Contingency analysis tools for maintaining system stability



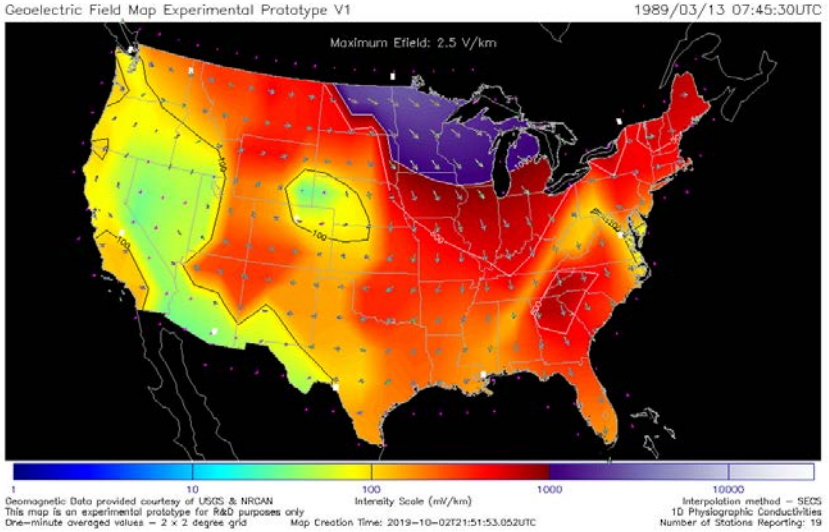
- System posturing
  - Start off-line generation and reactive resources
  - Issue conservative operations notices to transmission and generation operators
  - Limit electricity supply transfers out of constrained areas and coordinate with neighboring system operators

Real-Time Actions

- System operators adhere to established limits for voltage stability and equipment ratings
- Operating actions to maintain limits include
  - Dispatching generation
  - Load shedding schemes
  - Transmission system reconfiguration
- Manual operation of transformer cooling fans may increase thermal margin
- Maintain GMD operating procedures until four hours after storm conditions subside

Enhancements to Operating Mitigations

- SWPC near real-time geoelectric field mapping initiative will provide grid operators with improved situational awareness
  - USGS, NASA contributors
- Completion of Continental U.S. magnetotelluric survey will inform GMD vulnerability assessments and operations planning



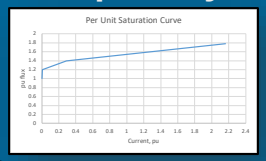
SWPC Prototype Geoelectric Field Map

GMD Research

NERC GMD Research Plan Objectives

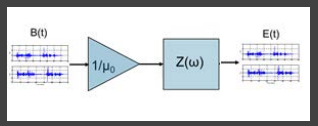
Improved Earth Conductivity Models

Improved Harmonic Analysis Capability

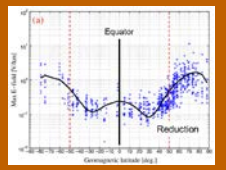


- Two-year research project with EPRI is concluding in 2020
- Further advance GIC modeling and system impact assessment
- Includes earth-space modeling contributions from national labs and NASA

Geoelectric Field Evaluation

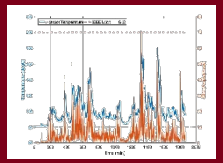


Latitude Scaling Factor



Harmonic Impacts

Transformer Thermal Impacts



Spatial Averaging

$$E_{peak} = 8 \times \alpha \times \beta \text{ (V/km)}$$

α= Geomagnetic Latitude Scaling Factors

β= Conductivity Scaling Factor

Going Forward

- Electricity is vital to society – high Impact / low Frequency events like severe GMD require special attention
- Reducing risk can be achieved through a mix of operating mitigations and system enhancements
- Science and engineering are rapidly evolving through space weather research, data collection, and grid analysis tool development

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